Distr.
LIMITED

E/ECA/NRD/CART/137
17 August 1989

Original: ENGLISH

UNITED NATIONS

ECONOMIC AND SOCIAL COUNCIL

ECONOMIC COMMISSION FOR AFRICA

Seventh United Nations Regional Cartographic Conference for Africa

Ouagadougou, Burkina Faso
6-11 September 1989

UN/NAIROBI

USE OF LANDSAT TM IMAGERY FOR UPDATING A 1:50,000 SCALE MAP OF MOUNT ELGON FOREST RESERVE IN UGANDA

by

S.N. Kalyango
Regional Centre for Services in Surveying,
Mapping and Remote Sensing

I. INTRODUCTION

1. The present uncontrolled and irrational destruction of the natural forests in equatorial Africa is likely to drastically offset the balance of the ecosystem of our habitat and thus accelerate the desertification process in the region. Conservation of forests does not only ensure continued supply of wood for timber, charcoal and firewood but also protection of the numerous renewable and non-renewable resources such as soil, water, flora and fauna, all of which are collectively important for the existence of mankind.

2. Continued existence of the humid tropical rain-forests and montane forests in East Africa is threatened by agricultural encroachment and indiscriminate deforestation. The rate and extent of depletion are not determined in most cases due to lack of effective monitoring systems, coupled with limitation of timely resource data and technical manpower to analyse and assess it. This situation has been triggered and, even, enhanced by human population explosion, economic pressure and unpredictable political climate where search for personal wealth has overweighed national interests among societies, thus crippling the law enforcement systems (UNEP, 1988) on the protection of the forest reserves. Uganda has probably gone through all this hard experience like many other countries and, during the course, it has lost large proportions of its natural forests to agriculture including the most precious humid tropical rain-forests and montane-forests. For example, Uganda had a total of 3,090,100 ha (12.7 per cent of the total land) of tropical high forest in 1900 as compared to 729,865 ha (3.03 per cent) in 1987 (UNEP, 1988).

3. This study was motivated by the results of the Uganda environmental data base project, funded by the United Nations Environmental Programme (UNEP) in 1987. The author participated effectively in the analysis of the multi-data LANDSAT MSS imagery for the assessment and mapping of land-use change between 1973 and 1986. Two land-use/cover map overlays were produced from this data set for UNEP at a scale of 1:500,000. The information so obtained was digitized into the geographical information system (GIS) data base of Uganda (GRID, 1987) by the Global. Resource and Information Data which operates under the auspices of UNEP.

4. The results of this project (UNEP, 1987) revealed the danger of rapid destruction of the forest reserves in Uganda. About 1,000 km^2 (1 per cent) of natural forest were assessed to have been transformed into agricultural land between 1973 and 1986. Based on this information, the Regional Centre for Services in Surveying, Mapping and Remote Sensing (RCSSMRS) decided to conduct a more detailed study with the higher resolution LANDSAT TM data for Mt. Elgon central forest reserves.

II. OBJECTIVES

5. The objectives of the study were:

(a) To examine in detail a set of multi-data TM imagery in order to assess the extent and nature of agricultural encroachment and other types of related deforestation activities in Mt. Elgon central forest reserves;

(b) To develop a simple methodology for forest map update based on manual interpretation of satellite remote sensing data which is easy and cheaper

to use in the field (provincial and district level) where sophisticated computer systems may not be available;

(c) To estimate the amount of forest that has been removed in favour of crop cultivation or other activities based on 1962 and 1973 map and/or satellite information;

(d) To demonstrate the capability of LANDSAT TM data to provide sufficient information for revision of forest cover and up-date the 1:50,000 map scale.

6. The target area of the study is located in the Mt. Elgon central forest reserve between longitude/latitude, 34° 40', 34° 45' and 1° 06', 1° 37' respectively. This area lies just on the eastern border of Uganda with Kenya in Kapchorwa district as shown in fig. 1. It covers approximately 1,036 km^2 including part of the forest, the Moorland zone and the extensive grasslands on the northern side of the mountain. The reserve area, therefore, covered only 505 km^2. This forest occupies the humid ferrallitic soils of the high altitude, mostly suitable for growing wheat and maize crops. It receives an annual rainfall ranging between 1,780 mm and 1,650 mm.

7. With such fertile soils and favourable climate, the forest has long been subjected to population land pressure as could be assessed from the demographic information on the 1:50,000 topographical map (1962) which was used in the study. According to the map, there were approximately 1,270 homesteads countes within an average distance of 3 km from the boundary at the time of the aerial photography in 1959 (the compilation material for the above topographical map). The average settlement density was estimated to be 5 homesteads km^2 at the time. The minimum and maximum were 1 and 15 homesteads respectively.

III. DATA SOURCE AND MATERIALS

8. LANDSAT TM, black and white films (8 x 9) and colour transparency materials (scale 1:1,000,000) were purchased from EOSAT company (USA) and processed at the RCSSMRS laboratory. Mt. Elgon forest reserve was covered on LANDSAT TM scene 170/059 of 10 February 1986.

9. Two types of photographic printing materials were used in creating these colour prints, namely the normal cibachrome paper and cibachrome II translucent. The latter allows sufficient amount of light to pass through it even when underlain with a base map print. In addition, it was possible to draw on it with a felt pen or water soluble plotting ink.

10. One topographical map, scale 1:50,000 series Y732 sheet no. 55/1, Edition 1-U.S.D., was used as the data base. Other data source materials included: reference topographical maps at scales 1:50,000, 1:250,000 and 1:2,000,000. Similarly, vegetation and soil maps, together with the UNEP/GEMS/GRID (1987) computer printouts of the Uganda environmental data base land-use/land cover maps, were used. Field information was also collected and integrated with the image interpretation.

11. The cost of data and other working materials used in this project is given in table 1. The rates of photographic processing are those charged at the Centre. The cost of expert labour for the interpretation is not given because this may vary with individuals and country.

Table 1: Cost of data materials

Item	Description	Rate ($US)	Total ($US)
1.	Original B/W Positives (Full Scene)	150.00	480.00
2.	False Colour Generation (Enhancement)	40.00	40.00
3.	Subscene Print (Translucent 16" x 20" x 40")	33.00/ 97.00	97.00
4.	3 Reference Map Sheets (All scales)	3.00	9.00
5.	Transparency, one metre	6.00	6.00
6.	Miscellaneous	10.00	10.00
	Total		642.00

IV. METHODOLOGY

12. As indicated earlier in section II, the objective of this study was to develop a simple and easy method of using satellite remote sensing data to detect forest cover changes which are associated with agricultural encroachment and/or general deforestation activities and use these results to up-date 1:50,000 scale map. The analysis and interpretation of LANDSAT imagery was done manually using the overlay method to compare two sets of data, i.e., the old map with recent imagery. Valerie (1980) described the approach as old-map/new source change detection method which can be used in the land-use/land cover map up-dating process.

13. The two types of printing paper materials were compared and used selectively, based on the quality and contrast of the original image. The original TM imagery was enlarged and matched to the base map scale of 1:50,000. This was then overlain with the topographic map for direct change detection. The scale match of the TM imagery print with the 1:50,000 topographical map was quite excellent.

14. The separation process of Mt. Elgon forest was based on spectral pattern signature as defined by colour tone (or colour shade), texture and shape . By using a light table and overlying the 1:50,000 scale topographical map of 1962 with the cibachrome II translucent print, the forest change was easily detected and discerned directly on the transparency. This permitted direct comparison of the 1962 old map with the new 1986 TM imagery. Seven land cover categories were discriminated within the forest boundary as shown in fig. 2 and table 3.

Each category was coded and the areas measured with a digital planimeter. The area change percentage was then calculated for each category as in table 3. Again each category area was measured, based on sub-county level, in order to relate the encroachment trends to the administrative boundaries. The results are given in table 5. In addition, the maximum and minimum distance of encroachment from the 1959 forest baseline was determined with a map measurer to locate where the deepest incursion occurred. The results are shown in table 4.

V. RESULTS AND DISCUSSION

15. The interpretation results yielded interesting information on the forest cover change and the extent of agricultural encroachment. In 1962, 1:50,000 scale maps was updated for forest cover using the LANDSAT TM colour image as shown in fig. 3.

16. The results obtained from the detailed analysis of LANDSAT TM image of the Mt. Elgon forest reserve are presented in tables 1, 2 and 3. Seven categories of cover types were identified and discerned as illustrated in Fig. 2. Based on the 1962 topographical map, 8,671 ha (27.4 per cent) of the forest land were encroached and totally replaced by agriculture in a period of 27 years. This is again supported by the fact that human population pressure on Mt. Elgon forest was recognized by the authority in 1983 (UNEP 1988) when 7,200 ha of forest land were officially degazetted in this reserve for settlement of people. The degazetted forest area was indicated on the map used in this study but the encroachment extended far beyond the marked boundaries according to the satellite imagery.

17. The soft wood plantation (category II) of 1,522 ha was established on the forest land as a replacement. This accounted for another 3.7 per cent of the removed natural forest.

Table 2: Deforestation trends in Mt. Elgon forest reserve area (ha)

Category	Description	1959	1986	% change
I.	Undisturbed natural forest	30,206	20.807	-46.9
II.	Soft wood plantation	56	1,522	+2617.8
III.	Moderately degraded	-	5,844	-
IV.	Severely degraded forest	-	2,418	-
V.	Forest totally replaced by agriculture	-	8,671	(27.4)
IV.	Moorland and heath	-	11,300	-

Table 3: Changes in the forest perimeter and encroachment distance on Mt. Elgon forest

Distance (km)

Item	Description	1959	1986	% Change
1.	Peripheral forest boundary	64	90	+40
2.	Maximum distance of encroachment	-	7	-
3.	Minimum distance of encroachment	-	1.4	-

Table 4: Deforestation trends in Mt. Elgon by sub-country categories - area in hectares

Sub-country	I	II	III	IV	V	Total
Bent	5,582	488	2,403	2,033	4,093	14,599
Chesoweri	3,103	110	598	-	583	4,394
Kabey	3,330	-	1,553	385	950	6,223
Chepkwasata	7,253	711	1,285	-	2,950	13,199
Kirwoko	733	-	-	-	-	733
Kapteret	513	-	-	-	-	513
Tigeres	18	-	-	-	-	18
Chema	275	-	-	-	-	275
Tulel	-	-	-	-	85	85
Kanyiyi	-	213	-	-	10	223
Total	20,307	1,522	5,844	2,418	8,671	39,262

18. The reforestation and crop cultivation together accounted for 25.9 per cent of the deforestation during the period of 27 years.

19. The information in table 3 confirms the change in the length of boundary of the forest from 64 to 90 km - a positive increase of 40 per cent. It also provides information on the maximum and minimum distance of clearing into the forest from the 1959 baseline. The longest distance of clearing into the forest was 7 km in Benet sub-county while, the shortest recorded was 1.4 km in Chepkwasata, Kono and again Benet sub-counties. This encroachment distance can also be used as a yardstick to locate spots where population pressure might be concentrating.

20. In summary, the agricultural encroachment (27.4 per cent) and reforestation (3.7 per cent) accounted for 31.1 per cent of the decline of the natural forest in the study area between 1959 and 1986. This figure is, however, very conservative, because it does not take into account the proportion of the cleared forest land in categories III and IV. For instance, the net deforested land in category III (severely degraded forest) was estimated to be 50 per cent. The results in table 4 show the forest in Benet sub-county to have suffered most with 4,093 ha (10.4 per cent) of forest land lost to agriculture. In other words, there was 20,807 ha (53.1 per cent) of "undisturbed" natural forest in 1986 as compared to 39,206 ha in 1959. Again, Benet sub-county was still leading in the severely degraded and moderately degraded forest by 2,403 ha and 2,033 ha respectively. Based on the 1959 baseline data, the negative forest change of 46.9 per cent (table 3) represents 18,399 ha of the natural forest which was destroyed.

VI. CONCLUSION

21. The results of this study have proved beyond doubt the potential for LANDSAT TM sensor system to provide useful information for detecting agricultural encroachment and deforestation in the montane forests.

22. The 30 m resolution TM data provided detailed information on Mt. Elgon forest and permitted a better insight into the forest. At a magnification of 1:50,000, cropped areas which are one hectare or more, could be detected although not measurable with a digital planimeter. This is an important characteristic of TM, because small plots of cultivation can be recognized in the forest (due to the strong contrast between the forest and bare soil). A dry season image is the best choice for identifying small parcels of cultivation in the forest on a TM image. The large consolidated areas of season crops (e.g., category V) like maize and wheat, which get dry during the dry season, were easy to recognize as a spectral pattern.

23. Monitoring of the forest cover changes and up-dating such information on 1:50,000 scale maps can be achieved in a time and cost effective manner by deploying multi-data LANDSAT TM imagery. The new encroachment line can be established by interpreting up-dated satellite information and producing current change maps. Such maps can be generated at selected intervals of one or two years within a minimum time of three months. The current operational LANDSAT 5 is capable of acquiring multi-data images over the same area frame every 16 days. Similarly, SPOT satellite can provide data at intervals of 27 days or less. A follow-up on this work is recommended in order to take advantage of this new technology and develop a monitoring system based on space data which can be acquired at programmed intervals.

24. Once these changes are defined, they can be transferred to the old maps by matching the image scale and use the cibachrome II translucent to print the enlarged imagery. This material allows direct transfer of the new information on to the old map or the corresponding map overlay. The method developed can be used to update the forest cover on 1:50,000 scale maps in a minimum time of one month per sheet given the satellite data.

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